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FREEZE-DRYING - PROGRESS AND PROBLEMS

"Freeze-drying is the newest thing in the dehydration world."

"Freeze-drying will be a \$2 billion, or a 4 billion pound business by 1970, investment advisory service predicts."

These two quotes are not mine. They were taken from recent articles in trade magazines and serve to illustrate the manner in which freeze-drying is tickling the imagination of food processors. A vice-president of one of our large food companies puts it this way:

"Men in the food processing industry are forever optimistic. They hope for a revolutionary processing innovation that will give the whole industry a boost. Right now, many processors feel freeze-drying is their panacea."

- * Is there a real growth potential in this new industry?
- * Will freeze-drying ever become a commonly used processing method for food?
- * What foods appear to be most adapted to this drying technique?
- * Who are potential users of freeze-dried products?
- * Will freeze-drying be substituted for other processing methods, or will it be used in addition to present methods?

These are good questions, but complete answers are not available.

What is freeze-drying?

Let us define freeze-drying so our thinking is channeled along the same lines. Here is an industry definition:

Presented by Kermit M. Bird, Agricultural Economist, Market Structure and Costs Branch, Marketing Economics Division, Economic Research Service, U. S. Department of Agriculture, Washington, D. C., at the Western Farm Economics Association Meeting, Reno, Nevada, August 6-8, 1962. Revised September 23, 1962.

"Freeze-drying is a unique food preservation process that removes moisture from frozen foods without appreciably changing the shape, color, or taste of the product. Cellular structure remains intact. With the water removed, the food can be stored for long periods of time without refrigeration. Moreover, the freeze-dried product loses 75% to 90% of its weight in the process. Reconstitution is accomplished by simply adding water or any other liquid."

To this, I would add that the dried product has a high attraction for water and oxygen. It must be carefully packaged to prevent reentry of these into the product. Bacterial action is kept to a minimum because of a lack of these two.

Basically, it's changing frozen foods (either cooked or uncooked) to the dry state by sublimation. This means that ice in the frozen product goes directly from solid to vapor, bypassing the liquid phase. This process takes place in a vacuum chamber at very low pressure and with a controlled input of heat. Foods emerge sponge-like, and the resulting "voids" aid in rehydration. Since only distilled water leaves the product, the oils and other carriers of flavors remain. The flavors also remain.

Although the technique is not new, processing innovations in recent years have lowered costs sufficiently so that now it is being considered as a food preservation method. It has been used for many years in the medical and drug fields, with blood plasma as a prime example.

Processing techniques

The first step in freeze-drying is preparation of the food. This is an important key to good quality end products. The procedure used depends largely on the product, although all products need to be sliced, diced,

granulated, powdered, or liquefied to keep the cycle time to about 8 hours. The food is frozen and these frozen foods are placed on trays, about two or three pounds per square foot. The trays are placed in a freeze-dry cabinet and the air pumped out of the cabinet. Heat is applied between the trays to the food and the sublimation process takes place—always at temperatures below the melting point of the product. When the core of ice within the product has disappeared, the temperature of the product rises, and the moisture level of the product has been reduced to two percent. It is now freeze-dried. The cabinet is back-flushed with nitrogen; the product is removed from the cabinet and goes to the final stage—packaging. Most products now on the market are nitrogen packed, although vacuum packing is used. Both cans and flexible pouches are being used as packages. Cans, however, appear to have an advantage in that they offer better protection to the friable product; and a satisfactory seal is easy with a can but difficult with a pouch.

Characteristics of freeze-dried products

Under proper conditions, freeze-drying preserves the structural, chemical, and physical integrity of foods. With the exception of freezing, this process comes closer to maintaining original product characteristics than any other processing method. This is a primary advantage of the method. In our taste-panel work we are using frozen foods as standards of comparison.

Final products are dehydrated, not frozen. As such, they may be kept in room temperature storage over long periods of time with minimum deterioration. Length of storage period depends on the quality of the

original raw product, the care with which they were freeze-dried, and the seal of the container. They should be good for two years at room temperature.

Another aspect of the product is its lightness of weight. For example, if we were marketing raw, deboned chicken meat, for every 100 pounds of frozen product we could ship only 29 pounds of freeze-dried product. With 100 pounds of mushrooms, we would ship only 11 pounds of freeze-dried product, eleven percent of the original weight. The lightness of the product is somewhat offset by the weight of the container. With some foods, the can weight exceeds the product weight.

Undesirable characteristics of the product might include appearance. Many foods, especially the meats, look quite unappetizing without their natural moisture. Thus a package with a window probably will not be used for these products. The affinity for water might be listed as a disadvantage also, since it makes packaging especially difficult and costly. On the other hand, it is this same characteristic that is a distinct advantage since it enables the food to be rehydrated much more quickly and completely than other dry products. The necessity to nitrogen or vacuum pack may also be listed as a disadvantage.

It is not necessary to rehydrate these freeze-dry foods with water. For example, strawberries could easily be rehydrated with syrup, meats with water to which tenderizer has been added, and fish with water and lemon juice. There is no technical reason why any product could not be rehydrated with beer, wine, rum, or other spirits. This thought adds an exotic dimension to the potential use of these products.

Products that appear to have commercial application

Presently we have in this country about seven companies with products on the market. Two meat companies have lines of campers' foods. These include sausage, beef steak, swiss steak, hamburgers, pork chops, ham and eggs, scrambled eggs, chile and beans, chicken dices, green beans, peas, and shrimp creole. All these products are cooked and hot water may be used in rehydration. This line of camper foods may be a way of testing the market, because campers are only a tiny part of the total food market. Two prominent soup companies use freeze-dried components in their dried soups. Products are chicken and beef dices, onions, and mushrooms. Another firm is currently marketing for the institution trade, shrimp, chicken, and crab. On the west coast two firms do custom work--mainly in fruit and vegetable products. New products are continually being tested.

In USDA we have just finished a taste test of all freeze-dry products now on the market. Results of the test are not published yet, so my discussion of products is based only on my own subjective evaluation. My experience is derived from having tasted all products now on the market, plus a hundred or so others in various stages of development.

Chicken, turkey, and ham appear to have the greatest future among the meats. Several shell fish as shrimp and crab have already been market tested and are assured successes. Among the vegetables, asparagus and a few members of the cabbage family, for example, broccoli, have potential. Although I am not sure that mushrooms are a vegetable, I do feel sure they will be freeze-dried in large quantities. Among fruits,

blueberries, strawberries, raspberries, pineapple, apples, apricots, and others appear economically feasible. I would guess that some products like fish cakes, sausages, stews, soups, puddings, and even whole prepared meals will have a decided market. Specialty foods that appear promising are seasonings, spices, coffee, and fruit powders.

Foods with a high protein or starch content usually freeze-dry easily. Foods high in fat or sugar freeze-dry rather poorly. This is not always true, for I have found avocado dries to an excellent state. When foods have high water content and loose structural characteristics, as for example watermelon, tomatoes, and cucumbers, it is quite easy to freeze-dry them, but virtually impossible to reconstitute them to their original form. If original form were not important, this method would work well, although it probably would be an expensive way of removing water.

Freeze-drying applications

Another way of assessing the potential of the industry is to examine possible markets for the products. These would include:

1. Institutional sales: Freeze-dried foods, such as shell fish, fish, meats, vegetables, are readily adapted to the portion-control method of mass feeding used in restaurants, schools, hospitals, and other away-from-home eating places. To some companies this sales outlet appears most promising. It's an \$18 billion market and growing larger each year.

2. Secondary processing: Freeze-dry ingredients added to soups, preserves, desserts such as gelatin, puddings, ice creams, and bakery products can improve food quality and the natural characteristics of processed foods. As an example, freeze-dried strawberry powder used as

a flavoring ingredient in gelatin desserts would materially upgrade the product. Several large food manufacturers are using freeze-dry products in this manner, and at present, this probably constitutes the largest commercial market for the products. Probably in the future this will be the outlet for a very sizeable volume of freeze-dry products.

3. Convenience foods: New freeze-dry products as camp packs, dip mixes, and unique confectioneries have been developed. There are strong indications that this market may be larger than one would expect.

4. Armed Forces: Probably the largest single buyer of freeze-dried products is the Quartermaster Corps. This year, or early in 1963, the Army and Air Force plan on purchasing $\frac{1}{2}$ million pounds of freeze-dry meat, poultry and seafood. Adoption of other freeze-dried items for the mobilization reserve ration should result in a continuing yearly requirement of 1-3/4 million pounds.

5. Retail: At present, none of these products are available on retail grocery shelves as single items. Here I am not including the secondary processed items mentioned above, nor am I including the camping foods since they are sold in sporting goods stores. People in the field agree this market is still several years in the future. It's an extremely tough market to break into with new products, and caution is indicated.

6. Specialty items: It is quite possible that, within this area, freeze-drying may have its greatest impact. As an example, instant coffee dehydrated by this method is said to yield a product with trueness to flavor unequalled by any other drying method. A prominent food company is now installing freeze-dry cabinets in their coffee plant. I anticipate

that the freeze-dry product will be used to blend with their air-dried instant coffee. This procedure is expected to make the resulting product more closely resemble home-brewed coffee.

Another group of items within this category are seasonings, powders, and spices. Techniques have been developed so that such items as parsley, thyme, tarragon, and wintergreen can be dried whole. Items in powder form would include orange and lemon peel, oregano, and members of the onion family. One processor on the west coast has done considerable basic work in this field and results look promising. Spice company researchers are scrutinizing products and costs.

Costs of freeze-drying

The future of the freeze-dry industry depends largely on two factors, quality of products and costs of processing. We have discussed quality of the products. Now, what about costs?

We in USDA are currently engaged in an economies of scale cost study of the freeze-dry industry. Although our cost data have been collected, they are now being analyzed and not yet available. Within a few months, we will have a publication on the subject of costs. Nevertheless, I will give you the opinions of some knowledgeable people currently operating freeze-dry plants. You will find, however, there is considerable difference in their cost estimates.

A custom freeze-dry plant has a rate of 10 cents per pound of raw product. This would be equivalent to 11 to 14 cents per pound of water removed. The manager of this plant feels this charge adequately covers his costs, even though the plant is not yet operating at full capacity.

At a new plant in Canada, it is estimated that costs may be as low as 2 to 3 cents per pound of water removed. Lowness of this estimate is largely attributed to low cost of electric power— $4\frac{1}{2}$ mills per KWH. However, some quick calculations with our data, using power at $\frac{1}{2}$ cent per KWH, show volume has to be up to about 32 tons of water per day to arrive at the 3-cent figure.

Mr. Robert Graf of Military Subsistence has this to say about low costs:

"We have heard many estimates of freeze-dry costs, some as low as 2 cents per pound of water removed. We recognize that existing facilities will not ordinarily provide such low production costs, but we regard most currently quoted prices as extremely out-of-proportion to reality."

Dr. John Nair, well-known consultant to the food industry, uses 7 cents per pound of water removed as a rule-of-thumb cost. Others say 7 cents would not even cover the overhead costs at present volume levels. A food technologist employed by one of the large freeze-dry processors puts average costs in the 5 to 7 cents range—depending on length of drying cycle, original moisture of product, type of heat used, and other factors.

There are many reasons for the present confusion concerning costs. First, the industry is new. Current operating plants are small. Probably the largest freeze-dry plant now in operation has a volume of about one-tenth the volume of an efficient canning or freezing plant. Then, too, the industry is in the experimental stage and the volume, small though it is, has to carry a large burden of overhead in terms of research

and development. Lastly, I suspect that each cost estimate is based upon different input quantities, varying costs per unit of input, and perhaps even quite different plant capacities.

Our cost study, when released this fall, will provide estimates that can take into account much larger volumes of production than are now being used. Economies in cycle time, staggered cabinets to even out the use of power inputs, use of labor, and overhead, appear important considerations related to volume. Other factors we have found important are size of plant, days per year it is used, hours per day, and the products being processed.

Potential of the industry

In summary, I would say that many products now being freeze-dried are quite acceptable. In general, most people who have tried the products agree that, when considered as dry products, trueness to flavor is maintained to a high degree. They have characteristics associated with other dry products, including ease of storage and handling. In addition, they are more easily rehydrated.

On the minus side, costs are high. Currently, they are much higher than other drying and processing methods, as canning and freezing. Also, our taste-panel results, to be released shortly, show some products to be decidedly poor. There are quite emphatic differences between the same products processed by different companies.

I personally feel the whole drying industry will be expanding and, within this industry, freeze-drying has an important place. Nevertheless, it appears that its major role will not be as a general drying method for

a wide range of foods. Rather, the area of use will be as a special drying method for products where it is desirable to retain a very high proportion of the flavor. I do not see wide usage of this process for large volume foods like peas, onions, potatoes, tomatoes, oranges, apples, and so on. All of these freeze-dry satisfactorily. But other drying methods provide products that are almost as good and at considerably lower costs.

If I were to guess the dollar volume of the freeze-drying industry in 1970, I would place the market at somewhere between $\frac{1}{2}$ and 1 billion dollars annually. This assumes total food sales will be about 87 billion dollars yearly. In eight years this is a potential of about $\frac{1}{2}$ to 1 percent of total food sales.

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